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HETEROSIS AMONG THE LINES SELECTED FOR PUPAL WEIGHT IN THE DIRECT AND RECIPROCAL HYBRIDS OF MULBERRY SILKWORM *BOMBYX MORI* L.

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ABSTRACT

Manifestation of heterosis in interbreed crosses of high, medium, low and control lines selected for pupal weight in silkworm is reported. Significant positive heterosis over better parent in the selected and correlated traits was obtained due to the wider genetic distance noticed in Pure Mysore (multivoltine) and NB18 (Bivoltine). Whereas, the magnitude of heterosis varied among interbreed crosses which involved all three types of gene effects (additive, dominance and epistatic interactions). The present study indicated that heterosis was more pronounced in the crosses involving bivoltine which happen to be either low male or female component and is clearly demonstrated in the heterosis averaged over male and female parents. Higher pupal weight does not necessarily result in higher heterotic values so, while selecting the parents for commercial exploitation differential pupal weight should also need to be considered.

Key words : Mulberry silkworm, pupal weight, selection, heterosis.

Heterosis in crosses among breeds, inbred and long isolated strains has been observed in most farm and laboratory animals [1]. The bulk of experimental evidence in animals suggests that the dominance effect appears to be widely contributing to heterosis among cross besides interactions [2], epistatic [3] and genetic distance of the strains [4, 5]. The exploitation of heterosis is considered to be one of the outstanding achievements in silkworm breeding. In silkworm, many quantitative characters are closely associated with nature of voltinism and maturity period, which are known to be sex linked [6-10] and expression of heterosis varies in the reciprocal crosses. Attempts have also been made to evaluate the crossing effects in the lines of mice [11, 12] and silkworm [13-15]. The objective of this study was to estimate the magnitude of heterosis in interbreed crosses of silkworm lines selected for pupal weight.

MATERIALS AND METHODS

After eight generations of selection for pupal weight interbred crosses were made among high, medium, low and control lines of two silkworm strains viz., Pure

Mysore and NB18. Females of the selected lines of Pure Mysore were crossed with males of selected lines of NB18 strain and reciprocal crosses were also made. The larvae of direct and reciprocal crosses were reared simultaneously along with their parents. Three replications of 100 larvae each were reared as per the standard technique [16]. The performance of nine traits namely, pupal weight, larval weight, single cocoon weight, shell weight, pupation rate, larval duration, filament length, denier and fecundity were recorded. The magnitude of heterosis was estimated over better parental (BP) value and tested for significance as per the standard statistical procedure.

RESULTS AND DISCUSSION

The performance of all the hybrids in respect of pupal weight, larval weight, (except M × M), cocoon weight, shell weight, pupation rate (except in three crosses), larval duration, filament length (except H × M) and fecundity was superior than their parents (Tables 1, 2). However, the size of the filament was higher than that of their parents which is not desirable. The heterosis was positive and significant in respect of pupal weight, cocoon weight, (except M × C), fecundity and denier. Negative and significant heterosis was registered in respect of larval duration (except in C × L and H × C). Six crosses viz., L × L, C × L, H × C, M × C, L × C and C × C in respect of larval weight, four crosses (H × H, H × M, L × M and H × C) in respect of pupation rate exhibited significant positive heterosis. In respect of shell weight, and filament length H × L cross alone registered positive and significant heterosis. The crosses involving the low lines as male components [H × L, M × L, L × L and C × L] yielded higher magnitude of BP heterosis for all the traits (except larval duration and pupal rate). Similar trend was also obtained when estimate of BP heterosis was average over male and female components (Table 5).

The effects of selection for pupal weight, were reflected in the heterosis over BPV for selected and unselected traits. The significant and positive heterosis observed in the selected and correlated traits of interbreed crosses may be due to the wider genetic distance noticed in pure mysore and NB18 strains [4,5]. However, the magnitude of heterosis varied among interbreed crosses depending upon the frequency of fixation of additive and dominance effect and epistatic interaction. Further, because of random drift, the gene frequency in two different lines will not be the same for all pairs. Hence it is not surprising that different pair of lines show different amount of heterosis. The manifestation of heterosis in pupal weight, larval weight, and shell weight, mainly may be due to over dominance and epistatic interaction, since significant and positive heterosis was observed over superior parents. Heterosis in cocoon weight, was recognised as due to over dominance and epistatic interactions

Table 1. Mean performance of parents and cross breeds among selected lines for different quantitative traits in multi × bivoltine hybrids

	LW	SCW	PW	SW	PR	TLD	FL	D	FEC
Parents									
Bivoltine (NB_{18})									
High (H)	3.520	1.291	1.048	0.244	5.97	26.958	903	2.10	491
Medium (M)	3.222	1.263	1.019	0.246	15.11	26.792	886	1.91	377
Low (L)	2.067	0.811	0.660	0.151	50.86	26.333	651	1.49	342
Control (C)	2.351	1.010	0.821	0.188	38.89	26.333	781	1.80	386
Multivoltine (Pure Mysore)									
High (H)	1.544	0.808	0.706	0.102	60.27	29.500	421	1.98	3.44
Medium (M)	1.418	0.732	0.636	0.096	73.38	29.333	387	1.83	343
Low (L)	1.168	0.584	0.510	0.073	75.43	29.000	270	1.69	312
Control (C)	1.489	0.701	0.606	0.095	81.14.	29.417	355	1.88	325
(Pure mysore × NB_{18})									
*H × H	2.871	1.400	1.159	0.241	71.10	26.458	710	2.14	561
M × H	2.840	1.367	1.127	0.240	50.33	26.333	724	2.24	467
L × H	2.849	1.381	1.152	0.229	56.10	26.167	687	2.15	539
C × H	2.957	1.332	1.117	0.215	37.80	26.167	678	2.16	527
H × M	2.938	1.281	1.071	0.210	80.17	26.167	595	2.21	543
M × M	2.302	1.316	1.093	0.223	40.60	26.458	653	2.03	538
L × M	2.569	1.261	1.044	0.217	85.00	26.333	604	2.07	549
C × M	2.625	1.292	1.064	0.228	61.00	26.333	661	2.13	556
H × L	2.563	1.309	1.082	0.228	59.40	26.167	738	2.00	589
M × L	2.711	1.237	1.024	0.213	65.00	26.167	701	1.91	581
L × L	2.306	1.174	0.981	0.193	68.30	26.167	607	2.06	502
C × L	2.562	1.224	1.022	0.202	48.30	26.458	673	2.02	542
H × C	2.754	1.319	1.086	0.233	77.80	26.458	705	2.08	531
M × C	2.709	1.100	1.071	0.212	72.20	26.333	588	2.01	517
L × C	2.561	1.237	1.031	0.207	68.90	26.333	620	2.18	560
C × C	2.758	1.310	1.090	0.221	76.10	26.333	697	2.12	565

*The first letter in the cross denotes female parent.

LW - Larval weight (g), SCW - Single cocoon weight (g), PW - Pupal weight (g), SW - Cocoon shell weight (g), PR - Pupation rate (%), LD - Larval duration (days), FL - Filament length (m), D - Denier, FEC - Fecundity (no.)

Table 2. Percentage of heterosis over better parent in cross breeds among selected lines of Pure mysore × NB_{18} hybrids

Crosses	LW	SCW	PW	SW	PR	LD	FL	D	FEC
# H × H	−18.436**	8.390**	10.595**	−1.229	17.976*	−1.855**	−21.336**	8.094*	14.290*
M × H	−19.318**	5.559*	7.538**	−1.639	−31.357**	−2.318**	−19.822**	22.445**	−4.887
L × H	−19.062**	6.971**	9.923**	−6.147	−25.630**	−2.934**	−23.920**	27.416**	9.775
C × H	−15.994**	3.175	6.583*	−11.885	−53.416**	−2.934**	−25.581**	14.894**	7.331
H × M	−8.814**	1.425	5.103*	−14.634	33.020**	−.332**	−32.844**	15.707**	44.031**
M × M	−28.561**	4.184	7.315**	−9.411	−44.631**	−1.244**	−26.298**	11.131**	42.668**
L × M	−25.418**	−0.158	2.453	−11.789	12.682*	−1.744**	−31.828**	22.682**	45.623**
C × M	−18.528**	2.296	4.413	−7.894	−24.824**	−1.744**	−25.395**	13.121**	47.480**
H × L	−23.996**	61.405**	53.187**	50.993*	−1.438	−2.373**	13.364**	34.529**	70.767**
M × L	−31.156**	52.527**	55.151**	41.059	−11.356*	−0.633**	7.680	28.475**	69.295**
L × L	11.529**	44.760**	48.737**	27.563	−9.456	−0.633**	−6.660	368.565**	46.828**
C × L	23.947**	50.924**	54.848**	33.774	−40.476**	0.475*	3.379	36.099**	58.479**
H × C	17.141**	30.594**	32.277**	23.936	29.093**	0.475*	−9.731*	15.770**	37.564**
M × C	15.227**	−8.910**	30.459**	12.765	−1.537	0.000	−24.711**	11.874**	33.938**
L × C	8.932**	22.475**	25.578**	10.106	−8.661	0.000	−20.614**	29.191**	44.707**
C × C	17.295**	29.784**	32.670**	17.080	−6.215	0.000	−10.713*	17.996**	46.095**

The first letter in the cross denotes female parent, *Significant at P = 0.5

LW - Larval weight (g), SCW - Single cocoon weight (g), PW - Pupal weight (g), SW - Cocoon shell weight (g), PR - Pupation rate (%), LD - Larval duration (days), FL - Filament length (m), D - Denier, FEC - Fecundity (no.)

Table 3. Mean performance of parents and cross breeds among selected lines for different quantitative trait in BI × multi hybrids

	LW	SCW	PW	SW	PR	LD	FL	F	FEC
Parents									
Bivoltine (NB_{18})									
High (H)	3.520	1.291	1.048	0.244	5.97	26.958	903	2.10	491
Medium (M)	3.222	1.263	1.019	0.246	15.11	26.792	886	1.91	377
Low (L)	2.067	0.811	0.660	0.151	50.86	26.333	651	1.49	342
Control (C)	2.351	1.010	0.821	0.188	38.89	26.333	781	1.80	386
Multivoltine (Pure Mysore)									
High (H)	1.544	0.808	0.706	0.102	60.27	29.500	421	1.98	344
Medium (M)	1.418	0.732	0.636	0.096	73.38	29.333	387	1.83	343
Low (L)	1.168	0.584	0.510	0.073	75.43	29.000	270	1.69	312
Control (C)	1.489	0.701	0.606	0.05	81.14	29.417	355	1.88	325
(NB_{18} × Pure Mysore)									
*H × H	2.988	1.332	1.085	0.246	35.54	25.625	765	2.35	466
M × H	2.404	1.163	0.955	0.208	34.40	25.625	617	2.11	465
L × H	2.555	1.184	0.979	0.205	75.00	25.167	641	1.99	478
C × H	2.473	1.132	0.936	0.196	73.90	25.625	795	2.28	542
H × M	2.904	1.345	1.098	0.256	73.90	25.625	795	2.28	542
M × M	2.610	1.170	0.056	0.214	66.70	25.625	681	2.20	413
L × M	2.676	1.228	0.998	0.230	100.00	25.167	730	2.06	496
C × M	2.569	1.198	0.981	0.217	90.00	25.167	641	2.10	457
H × L	2.667	1.194	0.984	0.210	72.20	26.167	750	2.11	511
M × L	2.337	1.065	0.874	0.192	77.20	24.958	637	2.04	373
L × L	2.441	1.138	0.936	0.202	92.20	24.958	693	2.03	509
C × L	2.460	1.105	0.906	0.200	88.30	25.167	625	2.03	501
H × C	2.922	1.293	1.055	0.238	95.60	25.625	752	2.15	537
M × C	2.605	1.233	1.007	0.214	80.60	25.167	641	2.08	511
L × C	2.498	1.110	0.909	0.201	90.60	25.167	699	1.97	425
C × C	2.537	1.095	0.906	0.188	75.60	25.625	564	1.87	465

*The first letter in the cross denotes female parent.

LW - Larval weight (g), SCW - Single cocoon weight (g), PW - Pupal weight (g), SW - Cocoon shell weight (g), PR - Pupation rate (%), LD - Larval duration (days), FL - Filament length (m), D - Denier, FEC - Fecundity (no.)

Table 4. Percentage of heterosis over better parent in cross breeds among selected lines of NB_{18} × Pure mysore hybrids

Crosses	LW	SCW	PW	SW	PR	LD	FL	D	FEC
# H×H	–15.131**	3.150	3.595	0.819	–41.029**	–4.946**	–15.282**	18.718**	–5.110
M×H	–25.385**	–7.920	–6.218*	–15.708	–42.920**	–4.355**	–30.399**	10.471	23.322**
L×H	23.605**	38.669**	35.502	24.447**	–4.430**	–1.486	33.632**	38.967**	
C×H	5.160	12.102*	13.920**	4.159	22.622**	–2.690**	–19.206**	17.069*	33.052**
H×M	–17.498**	4.144	4.836	5.202	0.782	–4.946**	–11.923**	24.635**	10.315
M×M	–19.003**	–7.379	–6.186*	–12. 999	–9.037	–4.355**	–23.138**	20.438**	9.337
L×M	29.458**	51.418**	51.339**	51.929*	36.376**	–4.430**	12.141*	38.565**	44.879**
C×M	9.257**	18.673**	19.420**	15.133	22.738**	–4.430**	–17.883**	15.146*	18.060*
H×L	–24.240**	–7.538	–6.061	–13.758	–4.286	–2.937**	–16.980**	24.655**	4.165
M×L	–27.475**	–15.628**	–14.220**	–22.207	2.342	–6.843**	–28.104**	20.710*	–1.175
L×L	18.091**	40.362**	41.940**	33.627	22.227**	–5.222**	6.506	36.323**	48.952**
C×L	4.636	9.477	10.248**	6.106	17.057**	–4.430**	–19.974**	20.316**	29.569**
H×C	–16.987**	0.142	0.700	–2.396	17.816**	–4.946**	–16.685**	14.184	9.554
M×C	–19.148**	–2.336	–1.113	–13.067	–0.670	–6.065**	–27.652**	10.638	35.424**
L×C	20.851**	36.868**	37.727**	33.112	11.654*	–4.430**	7.373	32.735**	24.269**
C×C	7.910**	8.486	10.349**	–0.442	–6.832	–2.690**	–27.742**	4.082	20.172**

The first letter in the cross denotes female parent, * Significant at P = 0.05 **Significant at P = 0.01

LW - Larval weight (g), SCW - Single cocoon weight (g), PW - Pupal weight (g), SW - Cocoon shell weight (g), PR - Pupation rate (%), LD - Larval duration (days), FL - Filament length (m), D - Denier, FEC - Fecundity (no.)

Table 5. Estimates of heterosis (BPV) averaged over male and female components in the interline crosses of NB_{18} × PM and PM × NB_{18}

		LW	SCW	PW	SW	PR	LD	FL	D	FEC
NB_{18} × PM										
Male	High	–2.938	13.326	12.492	6.193	–9.220	–4.105	–16.593	19.973	22.558
	Medium	0.554	16.714	17.352	14.816	12.715	–4.540	–10.201	24.696	20.518
	Low	–7.47	6.668	7.977	0.942	9.335	–.858	–14.638	25.501	20.378
	Control	–1.843	10.790	11.915	4.301	5.492	–4.533	–16.176	15.410	2.354
Female	High	–18.464	–0.026	0.768	–2.53	–6.679	–4.44	–15.218	20.548	4.731
	Medium	–22.753	–8.316	–6.934	–15.995	–12.571	–5.404	–27.323	15.564	16.727
	Low	23.001	43.655	42.418	38.542	23.676	–4.628	0.063	35.314	39.267
	Control	6.741	12.184	13.484	6.239	13.896	–3.560	–21.201	14.153	25.213
PM × NB_{18}										
Male	High	–18.02	6.024	8.659	–5.22	–23.107	–2.510	–22.665	18.212	6.627
	Medium	–20.330	1.937	4.821	–10.932	–5.938	–1.766	–29.091	15.660	44.951
	Low	–4.919	52.404	52.980	38.347	–15.681	–0.791	4.441	34.417	61.342
	Control	14.648	18.486	30.246	15.972	3.170	0.11	–16.442	18.708	40.576
Female	High	–8.526	25.453	25.291	14.766	19.663	–1.521	–12.637	18.525	41.663
	Medium	–15.952	13.340	25.115	10.694	–22.220	–1.049	–15.788	18.841	35.253
	Low	–6.005	18.512	21.673	4.933	–7.76	–1.192	–20.755	29.464	36.733
	Control	1.680	21.545	24.629	7.769	–31.233	–1.051	–14.577	20.527	39.846

LW - Larval weight (g), SCW - Single cocoon weight (g), PW - Pupal weight (g), SW - Cocoon shell weight (g), PR - Pupation rate (%), LD - Larval duration (days), FL - Filament length (m), D - Denier, FEC - Fecundity (no.)

while heterosis in shell weight, is due to complete dominance [17]. The results obtained in this study are partially in agreement with the above observation.

Mean values of the traits in respect of parents and their hybrids of reciprocal crosses are presented in Table 3 and 4 respectively. All the hybrids registered better performance than their parents in respect of pupal weight, larval weight, cocoon weight, shell weight, pupation rate, filament length (except M × H and C × C) and fecundity. The reduction in larval duration and increase in the size of the filament compared with their parents was noticed in all the hybrids. Larval duration and denier registered negative and positive BP significant heterosis respectively. The magnitude of heterosis over BPV was higher in the crosses involving the low lines as female components (L × H, L × M, L ×L and L × C) with an exception to larval duration and pupation rate. These findings are also further established when the BP heterosis is estimated averaged over male and female components (Table 5).

Among the heterosis averafed over male components in PM × NB18 and female component in NB18 × PM combinations, low selection lines registered high degree of positive heterosis over BPV (except larval duration and pupation rate). This indicated that a greater hybrid vigour is observed in those interbreed crosses in which bivoltine happened to be either low male or female component. Large genetic distance present in the hybrids involving low selection lines probably increase the heterosis [4,5]. Further, the mean values of cocoon weight, shell weight, and filament length in the direct crosses (M × B) were higher than their reciprocals (B × M) which supports the observations of Tazima [10]. First, it was proposed that maturity genes linked to Z chromosome play an important role in reciprocal hybrid differences since these genes have close relationship with body size, cocoon weight, shell weight, and body weight, [6]. Later, Marohoshi [7] proposed multiple allelism of maturity genes on Z chromosome and the differences for maturity in direct and reciprocal crosses. Further, this genetic mechanism involves voltinism, maturity genes, temperature during silkworm rearing and hormonal interplay seem to operate on the manifestation of the traits [18]. Significant negative BP heterosis obtained in the desired direction for larval duration indicated that the magnitude of heterosis was more in reciprocal crosses (B × M) than direct crosses (M × B). It is important to consider these results while utilising strains which differ in pupal weight, for developing superior F1 hybrids. The crosses involving bivoltine male (0.479 - 0.795 g) or female (0.706 - 0.882 g) with lower pupal weight, is one of the desirable component in hybridisation to obtain high magnitude of heterosis.

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